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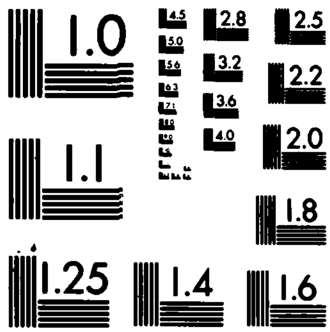

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TECHNICAL REPORT RG-84-6

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A FIELD EVALUATION OF THE BENDIX GYROCOMPASS NAVIGATION SYSTEM - LAND NAVIGATOR

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S. G. McDaniel
Guidance and Control Directorate
US Army Missile Laboratory

FEBRUARY 1984

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35898

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Bendix Gyrocompass Navigation System (GNS) is a low cost, moderately accurate land navigator intended for use in combat and service vehicles not requiring the accuracy of a weapon delivery system. A GNS was field evaluated. The course traversed included paved roads, dirt roads, and an extreme elevation change. The results including system and vehicle errors indicate a 1.40% of distance traveled system.

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I. INTRODUCTION

A. Description of Equipment

The Bendix Gyrocompass Navigation System (GNS) is a low cost, self-contained, dead-reckoning navigation system whose primary functions are to:

- Determine the orientation of the vehicle with respect to North
- Provide land navigation information in Universal Transverse Mercator (UTM) coordinates (northing/easting)
- Provide range and bearing information to operator-selected destinations

The GNS receives distance traveled information from an encoder attached to the vehicle odometer cable, and resolves this information, using its heading output, into incremental Northing and Easting. Continuous summation from the initial position provides present position information.

The GNS is configured as four Line Replaceable Units (LRU):

- Navigation Reference Unit (NRU)
- Navigation Display Unit (NDU)
- Display Computer Unit (DCU)
- Distance Measuring Unit (DMU)

The NRU sensing elements consist of a Directional Gyro (DG) and bubble levels details of which are company proprietary. The DG is rotated for initialization, then uprighted for navigation. The bubble levels sense changes in roll and pitch.

The GNS provides navigation capability within five minutes from power on. It provides the following additional capabilities:

- Realign - at operator request, with vehicle stationary, the GNS re-gyrocompasses within 3 minutes to normal accuracy.
- Position Update - the operator can insert new Northing/Easting updates, at any time, without impacting the GNS operational status.
- Navigation Calibration - at operator request, the GNS will automatically calculate the odometer scale factor and the azimuth crab angle of the NRU with respect to the vehicle longitudinal axis.
- DG Drift Update - The GNS automatically calculates DG drift, when the vehicle remains stationary for 2.5 minutes. This sub mode is automatically exited upon vehicle movement and does not impact operational status.

The GNS evaluated was a brassboard configuration consisting of production assets from the MLRS program which were modified for GNS usage. LRU size and weight did not reflect the production GNS form and fit. The function of the brassboard was that of a production GNS. The GNS system was designed for 2 percent of distance traveled (RMS) performance, when used for all phases of vehicle operation, including highway and cross country travel.

B. Test Objectives

The object of this study was to evaluate the land navigation capabilities of the GNS. The GNS has possible use as a low cost land navigator on such systems as Fiber Optic Guided Missile (FOG-M) and mobile land combat vehicles. The performance criteria were Defense Mapping Agency (DMA) survey points located in nearby Huntsville, AL. The GNS was driven directly over these points and its outputs compared to the known location of the points.

II. TEST PROCEDURE

The GNS was installed in a US Army step van with no precise alignment to the vehicle axis. The van was then driven over the course shown in Figure 1 to calibrate the odometer input and to determine the system and vehicle misalignment. Table I shows the location of the DMA survey points in UTM northing, easting, and elevation based on the Clarke 1866 ellipsoid. As can be seen, the course included a severe elevation change.

TABLE I. DMA SURVEY POINTS

DESIGNATION	NORTHING (M)	EASTING (M)	ELEVATION (M)
AP	3838102	537624	187
TOWER	3843154	545366	497
DEPOT	3843591	537522	190

Once the system was calibrated, actual runs were taken thusly:

1) the vehicle was parked at AP
2) the GNS gyrocompassed and initialized for approximately 4 minutes
3) having determined heading the system was ready to go
4) the van was driven to the DEPOT
5) the GNS outputs were recorded (northing, easting, distance)
6) the van was driven to the TOWER
7) the GNS outputs were recorded
8) the van was driven to AP
9) the GNS outputs were recorded.

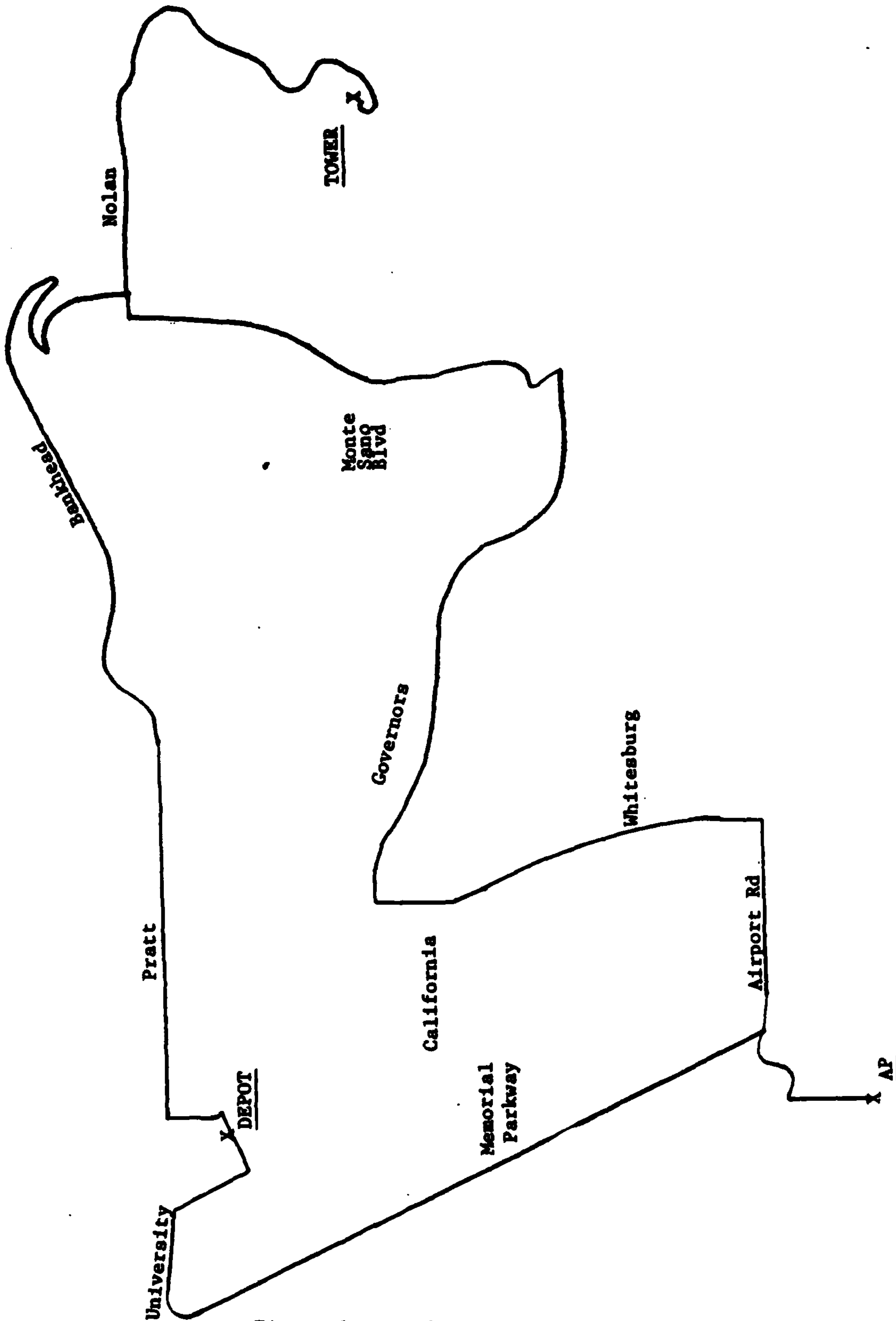

Figure 1. Land navigation course.

This procedure was repeated five times. The course was then run five times in the opposite direction. There were no system updates during the individual runs.

III. RESULTS

The results shown in Table II indicate an overall system performance of 1.40% (RMS) of distance traveled or a Circular Error Probable (CEP) of 381 m with a maximum move of approximately 40 Km over terrains that include severe elevation changes. These statistics were determined thusly:

1) RMS was calculated from the five runs of each direction for northing error, easting error, radial error, and % distance traveled

2) CEP was calculated using the following equation

$$CEP = .589 \, (\text{Northing Error}_{RMS} + \text{Easting Error}_{RMS})$$

Plots of radial error and CEP vs distance traveled are shown in Figures 2 and 3. Statistical calculations were also made for the performance of the system dependent on the direction the vehicle traversed the course (clockwise or counterclockwise). Interestingly, there is a difference. This difference seems to be related to the elevation change. A study of the flat portions of the course with no elevation inputs show a 1.00% (RMS) of distance traveled. The portions of the course that include flat or uphill inputs is .90% (RMS) of distance traveled. The % (RMS) of distance traveled for portions of the course after the TOWER is 1.76.

IV. CONCLUSIONS

The Bendix GNS is advertised as a 2% of distance traveled system. This study shows that it is a 1.40% or better system. Previous GNS demonstrations have indicated the system is better than 1% on flat terrain. This evaluation made use of flat terrain and a mountain which consisted of an elevation change of approximately 310 m.

Error sources for this evaluation include system sensitivity, road tilt, vehicle tilt, and changes in tire air pressure. Although there were no obvious changes, vehicle tilts on the winding roads up the mountain probably caused the tire pressure to change. This in turn affected the odometer input scale factor.

Whether or not the vehicle induced errors, this was a real demonstration of odometer input land navigation systems.

As was shown in the RESULTS section the largest portion of the errors were associated with the mountain. In the counterclockwise runs the errors came early and had a chance to build and affect the rest of the run. In the clockwise runs the mountain came later reducing the error buildup time.

TABLE II. BENDIX GNS RESULTS

COURSE LEG	CUMMULATIVE DISTANCE (m)	ERROR NORTHING (RMS) (m)	EASTING (RMS) (m)	RADIAL (RMS) (m)	% DIST TRAV (RMS)	CEP (m)
AP ⟶ DEPOT	8591	8	86	86	1.00	55
AP ⟶ TOWER by DEPOT	20906	104	113	153	0.73	128
AP ⟶ AP by DEPOT, TOWER	38817	321	371	490	1.27	408
CLOCKWISE		195	229		1.02	250
AP ⟶ TOWER	17930	103	135	169	0.94	140
AP ⟶ DEPOT by TOWER	30057	502	195	538	1.79	411
AP ⟶ AP by TOWER, DEPOT	38574	476	663	816	2.12	671
COUNTERCLOCKWISE		404	407		1.69	478
ALL RUNS COMBINED		317	330		1.40	381

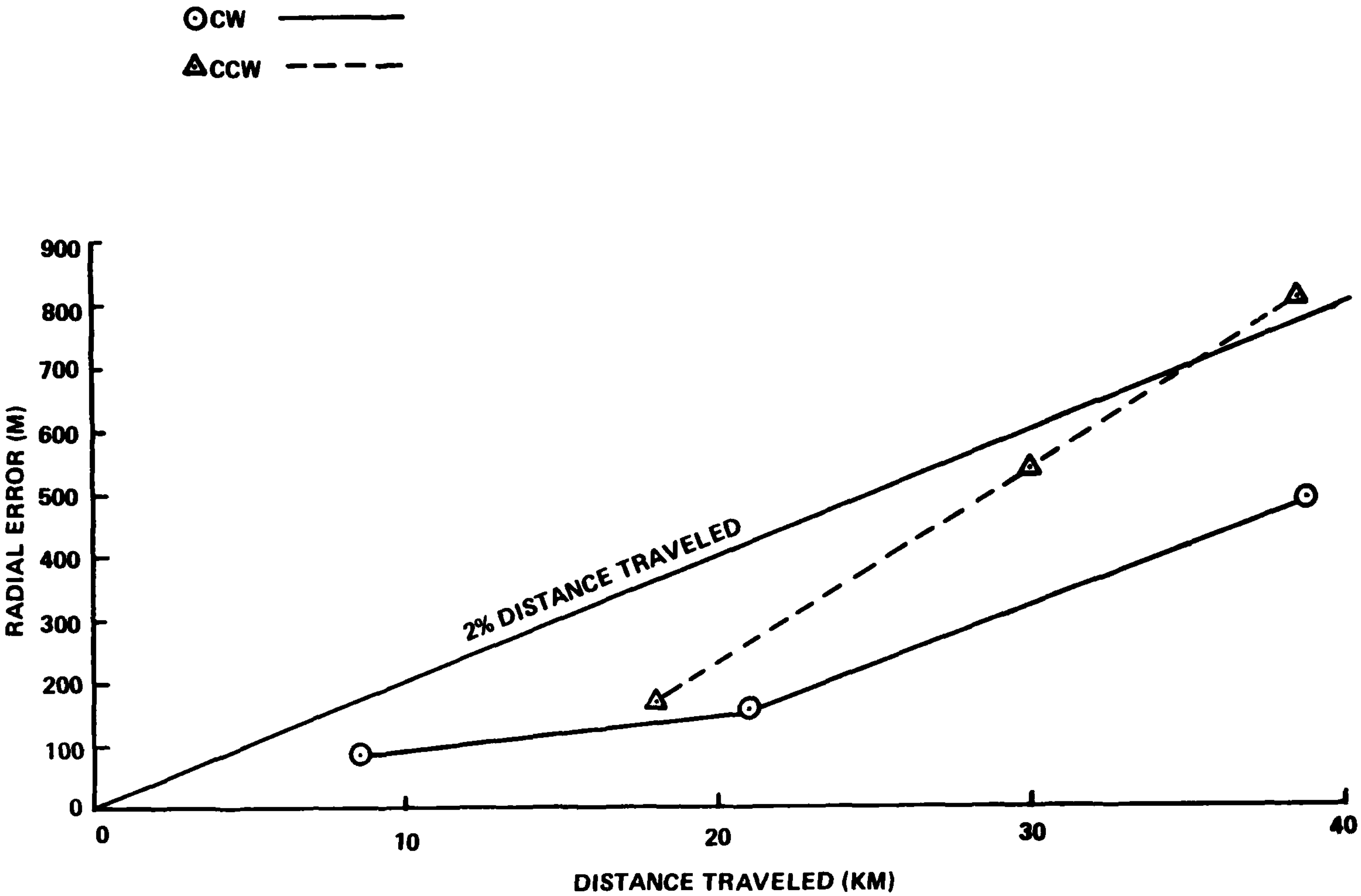

Figure 2. Radial error vs distance traveled.

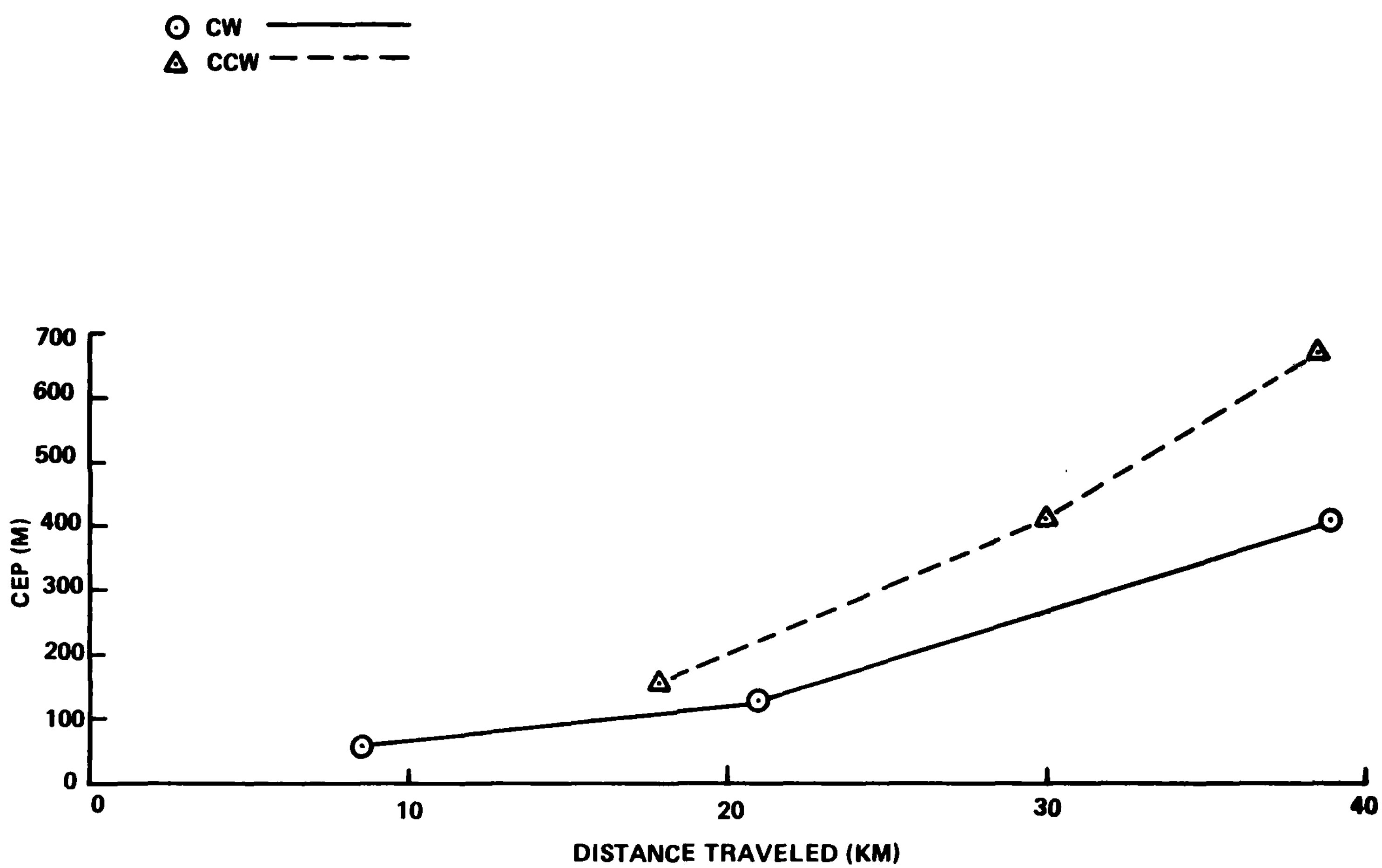

Figure 3. CEP vs distance traveled.

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